WEINGARTEN, SCHURGIN, GAGNEBIN & HAYES LLP
Ten Post Office Square
Boston, Massachusetts 02109
Telephone: (617) 542-2290
Telecopier: (617) 451-0313

Express Mail No: EM259611263US

Date: October 27, 1997

Attorney Docket No.: RTI-001XX

BOX PATENT APPLICATION
Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Transmitted herewith for filing is the **patent application** of:

Inventor: Robert S. Silvers

Entitled: DIGITAL COMPOSITION OF A MOSAIC IMAGE

Enclosed are:

[X] 5 sheets of informal drawings (one set)

[X] an Assignment of the invention to: RUNAWAY TECHNOLOGY, INC.

[ ] a Certified copy of a ______________________________ application

[X] a Verified statement re small entity status (§1.9 and §1.27)

[X] Information Disclosure Statement (2 references)

[ ] Continuation-in-part application of Application No. ______________, filed ______________.

[ ] Priority under 35 USC §119(e) is claimed of the following provisional application(s).

60/035,733 (Application Number)	January 2, 1997 (Filing Date)
______ (Application Number)	______ (Filing Date)
______ (Application Number)	______ (Filing Date)
______ (Application Number)	______ (Filing Date)

[ ] The above-identified provisional application(s) is/are assigned of record to:

[ ] The claim to small entity status in the above-identified provisional application(s) is made in this application and a copy of the Small Entity form(s) from the provisional application(s) is/are enclosed.

Express Mail Number

EM259611263US

TRANSMITTAL FORM FOR FILING PATENT APPLICATION (CONTINUED)

Attorney
Docket No.: RTI-001XX

[ ] ______________________ is hereby appointed Associate Attorney by:
Registration No.:

____
Attorney of Record:
Registration No.:

[ ] Other:

CLAIMS FILED:	MINUS BASE:	EXTRA CLAIMS:	RATE:	BASIC FEE:
				$790.00
Independent	2 - 3	= 0	x $82.00 =	0.00
Total	30 - 20	= 10	x $22.00 =	220.00
[ ] Multiple Dependent Claims (1st presentation)			+ $270.00 =	0.00
			SUBTOTAL FILING FEE	$1,010.00
Small Entity filing, divide by 2. (Note: verified statement must be attached per §1.9, §1.27, §1.28.)				$505.00
			TOTAL FILING FEE	$505.00

[X] The filing fee has been calculated above; a check in the amount of $505.00 is enclosed.

[ ] The filing fee will be submitted at a later date.

[X] The Commissioner is hereby authorized to charge payment of any additional filing fees under §1.16 associated with this communication or credit any overpayment to Deposit Account No. 23-0804. Note, unless the adjacent box is X'd, no authorization is hereby given to charge additional fees.

Attorney of Record: Eugene A. Feher
Registration No.: 33,171

EAF/rec
110466
SUBMIT IN TRIPLICATE

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

TITLE OF THE INVENTION

DIGITAL COMPOSITION OF A MOSAIC IMAGE

CROSS REFERENCE TO RELATED APPLICATIONS

A claim of priority is made to U.S. Provisional Patent Application Serial No. 60/035,733, filed January 2, 1997, entitled: DIGITAL COMPOSITION OF A MOSAIC IMAGE.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable

BACKGROUND OF THE INVENTION

The present invention is generally related to computerized manipulation of images, and more particularly to generation of an image from a plurality of sub-images.

Analysis and manipulation of images using computers is well known. For example, computers have been used to analyze images of coins travelling along a conveyor belt to distinguish different types of coins and compute the total value of the coins. Similarly, computers have been used to analyze images of integrated circuits and printed circuit boards in order to detect defects during manufacturing. Manipulation of photographic still images and full motion video images to produce special effects is also well known. However, these known techniques do not produce artistically pleasing mosaic images.

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

Express Mail Number
EM259611263US

BRIEF SUMMARY OF THE INVENTION

In accordance with the present invention, a mosaic image that approximates a target image is produced from a database of source images by analyzing tile portions of the target image, comparing each respective analyzed tile portion of the target image with the source images from the database to provide a best-fit match in accordance with predetermined criteria, and generating a mosaic image comprising the respective best-fit match source images positioned at respective tile portions of the mosaic image which correspond to the respective analyzed tile portions of the target image. In one embodiment the criteria for the best-fit match includes computing a version of Red, Green and Blue ("RGB") Root-Mean Square ("RMS") error. Other matching systems could be employed as long as the goal of finding the source image that is most visually similar to the region of the target image under consideration is met.

Increased resolution is realized in the mosaic image through sub-region analysis. In particular, each tile portion in the target image is divided into sub-regions which are independently compared with corresponding sub-regions of each source image using, in this example, RGB RMS error analysis. The computed RGB RMS error for each sub-region is summed to provide a sum RGB RMS error for the entire source image. The unallocated image having the lowest sum RGB RMS error is then allocated for use in the corresponding tile portion in the mosaic image. The use of sub-regions even benefits regions without detail and results in more uniform distribution of color by selecting lower contrast images for these areas of little high-frequency detail. Another embodiment employs a second pass to prevent a source image from being placed in a given location in the mosaic if it would have a lower error in another location.

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

BRIEF DESCRIPTION OF THE DRAWING

The invention will be more fully understood in view of the following Detailed Description of the Invention, in conjunction with the Drawing, of which:

Fig. 1 is a block diagram of a mosaic image generating system;

Fig. 2 is a block diagram of a database of source images;

Fig. 3 is a flow diagram that illustrates a method of mosaic image generation;

Fig. 4 is a diagram that illustrates tiles and sub-regions;

Fig. 5 illustrates the effect of sub-region analysis on source image selection; and

Fig. 6 illustrates the effect of sub-region analysis on final mosaic image resolution.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 illustrates apparatus for generating a mosaic image 10 from captured source images 12 to approximate a target image 14. In the disclosed embodiment a VHS video tape player 16 is employed to facilitate capture of source images from video tapes. The video tape player may be employed to single-step through a video tape to capture still images for use as source images. Alternatively, source images can be captured in real-time during playback of a video tape. A computer controllable laserdisc player 18 also can be employed to facilitate capture of source images. Laserdiscs are preferable to video tapes when the desired subject matter is available from both sources because of the higher quality and easy random access to still images available from laserdisc. In the disclosed embodiment a computer workstation 20 with a video input is employed to capture the source images 12 from the video tape player 16 and laserdisc player 18. The computer workstation also accepts the target image 14 as input, and is employed to

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

generate the mosaic image 10 from the target image and source images by executing mosaic software. The mosaic image 10 generated by the mosaic software comprises an array of tiles 22, where each tile 22 is a source image 12, and the overall appearance of the mosaic image 10 approximates the appearance of the target image 14. An editing computer 24 such as a Macintosh (TM), PC or UNIX (TM) based system equipped with image editing software such as Adobe Photoshop (TM) can be employed for editing the mosaic image 22, to produce an edited mosaic image 26. A printer output device 28 may be employed to print the edited mosaic image 26.

Captured source images 12 can be analyzed and stored in a database 30 that is maintained in the workstation 20. An add_images_to_database program is employed to analyze raw captured source images 12 and create new source images therefrom. More particularly, the add_images_to_database program accepts a list of filesystem directories, an image size, and an output path as input, and operates in response to open each designated directory and search for source images from which to crop and resize to the specified dimensions. The square is subsequently moved to the location specified by the output path. In one embodiment, if the source image is in landscape format, a square image is cropped from the center of the source image. If the source image is in portrait format, a square is cropped from between the center and the top of the source image. As a consequence, the square image is more likely to include the emphasized feature of the source image, such as a person's face, without clipping the edges thereof. The images are then stored in the database 30. The database 30 is a file system which holds the formatted images in directories that are categorized by subject matter and size.

Fig. 2 illustrates organization of source images 12 within the database 30 (Fig. 1). Source images 12 are categorized and placed under root nodes such as an animals root node 32, a people root node 34 or a places root node 36. To generate a mosaic image from source images of animals, the

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

animals root node 32 is selected for the mosaic software. Directly under the animals root node are subdirectories containing identical image files at different levels of resolution. An originals subdirectory 38 contains uncropped versions of each source image file at full size 40. The originals subdirectory 38 is maintained because source images may be recropped during mosaic creation if the results from the add_images_to_database program are unacceptable. Directories labeled 256 x 256 (pixels) 42 and 64 x 64 (pixels) 44 contain large versions of the formatted source images which are used primarily for outputting a final bitmap. In this example, a 32 x 32 (pixels) 46 directory contains source images which are used for viewing the mosaic image on the screen during the construction process. The 16 x 16 (pixels) 48, 8 x 8 (pixels) 50, and 1 x 1 (pixels) 52 subdirectories contain source images which are preloaded when the mosaic software is initialized. The source images in the 16 x 16, 8 x 8, and 1 x 1 subdirectories are employed for matching source images to target image during mosaic image generation. Directories of source images at other levels of resolution may also be maintained.

Fig. 3 illustrates a method for generating the mosaic image. Referring now to Figs. 2, 3 and 4, the target image is selected and loaded as indicated in step 60. A root node of source images in the database is then selected and loaded as indicated in step 62. More particularly, a database path is specified and a mosaic program is executed. The mosaic program reads source images from the section of the database indicated by the specified database path, analyzes the target image and selects a source image for use in each tile of the mosaic image. More particularly, source images having resolution corresponding to the selected number of sub-regions ("sub-region resolution") for the mosaic image are loaded into a linked list of structures:

```
struct an_image {
     char *path;          /pathname of file in database/
```

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

```
    char used;           /whether image has been used/
    unsigned short *r;   /RGB image data for RMS matching/
    unsigned short *g;
    unsigned short *b;
    struct an_image *next;    /pointer to next structure/
    struct an_image *previous; /pointer to prev structure/
} an_image;
```

For example, if each tile in the mosaic image is to contain 8 X-axis sub-regions by 8 Y-axis sub-regions, then 8 X 8 (pixels) images are loaded from the database. The size of the target image in pixels along each axis is equal to the number of output tiles multiplied by the number of desired sub-regions to be considered during the matching process, i.e., one pixel per sub-region along each respective axis. The respective numbers of tiles which will be employed for the X and Y axes of both the mosaic image and target image is then specified as indicated in step 64.

The mosaic program executes a matching process once the source and target images have been loaded. When the matching process begins, the target image is divided into "x" by "y" tiles 22, where (x, y) is:

(target_image_width / width_subsamples, target_image_height / height_subsamples)

A new tile is loaded as indicated in step 68. A new sub-region 66 is then loaded as indicated in step 70. Loading begins with the upper left sub-region 66 of the tile 22, and moves from left to right through each row, and from top to bottom by row. The source image pixel that corresponds to the loaded sub-region is then loaded as indicated in step 72.

The matching process analyzes tiles 22 individually on a serial basis. For each tile 22 in the disclosed embodiment, a variation of the average Root-Mean Square ("RMS") error of the Red, Green, and Blue ("RGB") channels of each sub-region 66 is compared to each respective

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

corresponding source image pixel, for each source image in the database that is of proper resolution and is not designated as "used." A RMS error between the loaded pixel and loaded sub-region is computed for RGB channels and kept as a running sum for the tile as indicated in step 74. If unanalyzed sub-regions exist in the tile as indicated in step 76, flow returns to step 70. If all sub-regions have been analyzed, as determined in step 76, then the running sum RGB RMS error is compared to the lowest such error yet computed for a source image and the tile as indicated in step 78. If the error sum is lower than any previously recorded error sum for the tile, the error sum value and an index to the source image are recorded as indicated in step 80.

When all of the source images have been analyzed for similarity to the tile, the source image with the least computed RGB RMS error is assigned to a tile in the mosaic image corresponding to the tile in the target image, i.e., in the same location in the image. More particularly, if other source images in the database have not been compared with the tile as determined in step 82, a new source image is loaded as indicated in step 84 and flow returns to step 70. If all source images have been compared with the tile as determined in step 82, the source image with the lowest sum error is allocated to the tile and marked as "used" as indicated in step 86. The assigned source image is marked as "used" so that source images do not appear more than once in the mosaic image.

The matching process is repeated for each and every tile in the target image. Upon completion, a list of source images is written to a text file which is used by a final rendering program to construct a bitmap from the full resolution versions of the source images. More particularly, if all tiles have been examined as determined in step 88, a list of the lowest sum error source images for each tile is written to a text file as indicated in step 90, and the mosaic program reads the list and assembles a bitmap as indicated in step 92. If unexamined tiles still exist as

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

determined in step 88, flow returns to step 68.

A variation of the matching process, including computation of RMS error, is implemented as follows:

```
/* The goal of this routine is to find which source
photographs are the most */
/* visually similar to a given region (grid-space) of the
target image. */

int find_matches(int x, int y)
{
     register i, rt, gt, bt;
     int low, result, ii, the tile;
     char imagename[256], best_path[256];
     unsigned short rmas[XMAX*YMAX], gmas[XMAX*YMAX], bmas
[XMAX*YMAX];

     the_tile = x+(y*sizex);

     /* For this given grid-location of the target image,
clear the list of errors. */
     /* This list will later contain the computed errors and
will be sorted from best */
/* to worst */

     for(i = 0; i < pixels; i++)  {
          tiles[the_tile].list[i].score=99999999;
          tiles[the_tile].list[i].rank = 0;
     }

     strcpy(imagename, filename);  /* Get the name of the
target image */

imagename[strlen(imagename)-3] = 's'; /* Make sure that it
has the proper filename extension */
imagename[strlen(imagename)-2] = 'g';
     imagename[strlen(imagename)-1] = 'i';

get_grid_space(rmas, gmas, bmas, x, y); /* Get the image data
for the desired region of the */
          /* target image and put it into three arrays. */

image = head_image;    */ Reset the linked-list of source
images to the beginning */

while(image->next != NULL) {   /* For every source image we
are considering */

     result = 0;

/* This is a variation of RGB RMS error. The final square-
root has been eliminated to */
/* speed up the process.  We can do this because we only care
about relative error. */
```

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

```
/* HSV RMS error or other matching systems could be used
here, as long as the goal of */
/* finding source images that are visually similar to the
portion of the target image */
/* under consideration is met. */

for(i = 0; i > size; i++) {
     rt = (int)((unsigned char)rmas[i] - (unsigned
     char)image->r[i]);
     gt = (int)((unsigned char)gmas[i] - (unsigned char)
     image->g[i];
     bt = (int)((unsigned char)bmas[i] - (unsigned
     char)image->b[i];
     result += (rt*rt+gt*gt+bt*bt);
}
i = 0;

     /* The following code takes the error computed for the
last source image and inserts */
     /* it into a sorted list of all of the source images.
The list is shifted towards the */
     /* end to make room for this insertion */

     if (result < tiles[the_tile].list[pixels-1].score) {
          while((result > tiles[the_tile].list[i].score)
&&(i++ < pixels));

     for(ii = pixels-1; ii> i; ii--) {
          tiles[the___tile].list[ii}.score = tiles[the
          tile].list[ii-1].score;
          tiles[the____tile].list[ii].rank = tiles[the
          tile].list[ii-1].rank;
          tiles[the___tile].list[ii].pointer = tiles[the
          tile].list]ii-1].pointer;
}
          tiles[the_tile].list[i].score = result;
          tiles[the_tile].list[i].rank = i;
          tiles[the_tile].list[i].pointer = image;
}
     /* Now let's move to the next source image and repeat
     until we run out */

     image = image->next;

     } /* while */

/* Since the list is sorted from next to worse, we can see
the best tile by looking at */
/* the first list entry. */

low = tiles[the_tile].list[0].score;
tiles[the_tile].score = tiles[the_tile].list[0].score;
tiles[the_tile].rank = tiles[the_tile].list[0].rank;

strcpy(best_path, tiles[the_tile].list[0].pointer->path);
```

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

```
/* Do not let this image get replaced later because it was specified as required for the mosaic.*/
tiles[the_tile].required = tiles[the_tile].list[0].pointer->required;

strcpy(tiles[the_tile].path, best_path);
sprintf(imagename, "%s/%s", disp_version, best_path);

/* We now have a sorted list of source images from most-visually-similar to least-visually-similar */
/* for this grid location of the target image.*/

return low;

} /* find_matches () */
```

A second routine is used in one embodiment of the invention to take the sorted list from the previous routine and not only ensure that each source image is only used once but also to see that a given source image will not be selected for one region if it is an even lower match in another.

```
     /* In the first phase of the program (find_matches ()), e created a sorted list of source images */
     /* for each grid-space of the target image.  Since we do not want to repeat source images within */
     /* the mosaic, each grid-space cannot have its first choice source image (a source image may have */
     /* the lowest match for more than one grid location). The purpose of this routine is to decide which */
     /* of the grid locations actually gets to use the source image.  For example, it will not be placed */
     /* in one grid location if it an even better match to another */

int optimize ()
{

     int i, x, deepest = 0, change, a, step, which;

     /* For each of the grid-locations in the target image (number of tiles in the final mosaic) */
     /* This an N^2 algorithm, so we must loop twice to ensure that we consider all images for */
     /* all grid-locations. */
     for(a = 0; a < pixels; a++) {
          change = 0;

          /* For each of the grid-locations in the target image (number of tiles in the final mosaic) */
     for(x = 0; x < pixels; x++) {
          which = 0;
```

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

```
        do {
              step = 0;
              for(i = 0; i < pixels; i++) {

                    /* If tile is wanted more somewhere else, give
it to them. */
                    /* We do this by going through all the top
choices for the other grid locations. */
                    /* If we see the same source image listed as
the first choice at another grid */
                    /* location, we check to see if it is a better
match at the other location. */
                    /* If it is, we move through our sorted list
to the next best match for our current */
                    /* grid-location and do this until we find a
source image that is not a better match */
                    /* anywhere else.  When we find this, we can
keep it.  The variable "step" stays as 0 and */
                    /* we exit the do-while loop */
                    if   ((tiles[i].   rank    <=    which)    &&
(!strcmp(tiles[x].list[which].pointer->patch,
tiles[i].path))) {
                          /* If rank is same, check scores. */
                          if   ((tiles[i].rank    ==    which)    &&
(tiles[i].score > tiles[x].list[which].score)) continue
                          if (i == x) continue;
                          which++;
                          step = 1,
                          i - pixels; /* Skip to while. */
                    }
              }
        } while (step);

        if (which > deepest) deepest = which;

        /* Now that we found the most visually-similar source
image that is *not* a better match in another */
        /*  grid  location,  we  se  the  name  of  the  image  as
associated with this grid-location of the target */
        /* image. */

        if (strcmp(tiles[x].path, tiles [x].list[which].pointer-
>path)) {
        change++;
        strcpy(tiles[x].path,    tiles[x].list[which].pointer-
>path);
        tiles[x].required    =    tiles[x].list[which].pointer-
>required;
        tiles[x].score = tiles[x].list[which].score;
        tiles[x].rank = which;
}

} /* for */

/* If we go through all of the grid-locations and we do not
need to replace any */
```

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

```
/* tiles as being a better match in another location, we can
exit the routine now. */
if (!change) break;

fprintf(stderr, "\n%d/%d, %d changes (deepest is %d)\n", a,
pixels-1, change, deepest);

/* We need to loop back with this for loop as many times as
there are grid-space in the final mosaic. */ } /* for */

} /* optimize() */
```

A rendering program can be employed to produce the mosaic image following the matching process. The rendering program reads the list of the selected tiles, locates the full sized version of each respective corresponding source image in the database, and binds the located source images together to create a bitmap. The tiles in the mosaic image may be separated by a line to discretize them when viewed from close proximity. From a distance, the gridlines should be thin enough to disappear completely to the human eye, so as not to interfere with the seamlessness of the mosaic. The bitmap is then saved in a standard format to be displayed on a monitor or output in printed form.

The digital mosaic image can be printed in different ways, depending on quality, price and size constraints. Film recording and photographic printing may be employed. An image can be written to photographic film using a film recorder. Once the image is on chrome or negative, it can be printed on normal photographic paper. This option is best for a moderate number of small copies as writing the image onto the film is a one time cost. Direct digital printing potentially produces the highest quality, but each print is expensive. Digital printers employ either continuous-toning or half-toning. Continuous-tone printers deposit an exact color for each pixel in the image. Half toning printers deposit only drops of solid color, forming shades of color by using dots of different sizes or different spacing. Hence, the print will look less photographic. Process color printing is the technique used to reproduce images in magazines and books, and is a good method for producing many

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

(e.g., hundreds of thousands) near-photographic copies.

The effects of sub-region based analysis on source image selection are illustrated in Fig. 5. A target image 100 was employed to produce first, second and third mosaic images 102, 104, 106, respectively. The target image 100 includes 4 X 4 tiles. An intermediate "sensed" image representing the average of all pixels in the smallest analyzed portion (tiles in image 108, and sub-regions in images 110 and 112). In the first analysis, resulting in images 108 and 102, sub-regions are not employed. In the second analysis, resulting in images 110 and 104, 4 X 4 sub-regions per tile are employed. Because some light and dark regions can be sensed within each tile in the second analysis, those sensed regions are taken into consideration when searching the database during the selection process.

In the third analysis, resulting in images 112 and 106, 16 X 16 sub-regions are employed. With 16 X 16 sub-regions, the intermediate image 112 is substantially closer to the target image 100. Further, image 106 shows that when this amount of detail is considered during the selection process, more appropriate matches are selected. For example, the woman in the first row is the same shape as the vertical black bar in the same region of the target image. Further, the lizard in another tile matches the diagonal that it was compared to. This high-degree of shape matching has a powerful effect on the image-forming ability of the final mosaic image as information about the contours and shading in a target image may transcend the boundaries of each mosaic tile.

In addition to providing improved source image selection, the use of sub-regions results in more uniform distribution of color by selecting lower contrast images for regions of little high-frequency detail. This can be seen in the lower eight tiles of image 106 which are more uniform than those selected for image 104.

Fig. 6 illustrates the effects of number of sub-regions on mosaic image resolution. First and second mosaic images

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

144, 116 were generated from a target image 118. The first mosaic image 114 was generated with 2 x 2 sub-regions within each tile considered during the source image selection process. The second mosaic image 116 was generated with 16 x 16 sub-regions within each tile considered during the source image selection process. The same collection of source images was employed to produce both the first and second mosaic images. Because of the sub-region analysis, different source images were selected to represent some corresponding tiles in the first and second mosaic images. Further, the second mosaic image 116 bears a stronger resemblance to the target image 118 than the first mosaic image 114. Hence, improved source image selection provided through analysis of more sub-regions generates improved resolution in the resultant mosaic image.

In an alternative embodiment, semantic content is specified for portions of the mosaic image. More particularly, image sub-categories are specified for use with specified tiles of the target image. Hence, the resultant mosaic image includes tiles or regions of tiles with predetermined categories of images.

In another alternative embodiment images can be selected for assured selection and inclusion in the mosaic image. More particularly, the selected images are placed in the location of greatest visual similarity relative to the target image even if another (unassured) image is determined to have greater visual similarity.

Having described the preferred embodiments of the invention, other embodiments which incorporate concepts of the invention will now become apparent to one of skill in the art. Therefore, the invention should not be viewed as limited to the disclosed embodiments but rather should be viewed as limited only by the spirit and scope of the appended claims.

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

CLAIMS

What is claimed is:

1. A method for generating a mosaic image with an appearance that approximates a target image by utilizing a plurality of source images and a computer, comprising the steps of:

loading the target image into the computer;

dividing the target image into a plurality of tile regions, each tile region representing a distinct locus of the target image, and

for each tile region:

comparing source images to the tile region to produce a measurement of visual similarity, said comparing step including analyzing a plurality of individual portions of each source image;

selecting the source image with the highest measurement of visual similarity to represent the tile region; and

positioning the selected source image in the mosaic image at a locus corresponding to the locus of the tile region.

2. The method of claim 1 including the further step of dividing the tile region into distinct sub-regions, each sub-region corresponding to a specific portion of the source image, and comparing each respective sub-region with each respective source image portion to produce the measurement of visual similarity.

3. The method of claim 2 including the further step of employing source images having one pixel per respective sub-region.

4. The method of claim 1 wherein said comparing step includes the further step of computing the average Root-Mean Square error of Red, Green and Blue channels.

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

5. The method of claim 1 including the further step of removing source images selected in said selecting step from consideration such that no one source image appears more than once in the mosaic image.

6. The method of claim 1 including the further step of capturing source images, and storing the captured source images in a database.

7. The method of claim 6 including the further step of generating modified source images by cropping the source images captured in said capturing step to square.

8. The method of claim 7 including the further step of, in the case of a captured source image in landscape format, cropping the captured image from center.

9. The method of claim 8 including the further step of, in the case of a captured source image in portrait format, cropping the captured image from above center.

10. The method of claim 7 including the further step of categorizing the captured source images within the database.

11. The method of claim 7 including the further step of storing the captured source images at different levels of resolution.

12. The method of claim 1 including the further step of deselecting the source image with the highest measurement of visual similarity if it is determined that the source image has a higher measurement of visual similarity to another tile region.

13. The method of claim 1 including the further step of specifying at least one source image for assured inclusion in the mosaic image, the assured source image being

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

positioned in the mosaic image at a locus corresponding to the locus of the tile region having the highest measure of visual similarity therewith.

14. The method of claim 1 including the further step of specifying a sub-category of source images for exclusive matching with a predetermined portion of the target image.

15. An apparatus for generating a mosaic image with an appearance that approximates a target image by utilizing a plurality of source images, comprising:

A computer workstation that executes mosaic generation software being operative to divide the target image into a plurality of tile regions, each tile region representing a distinct locus of the target image,

said mosaic generation software being further operative to operate upon each tile region to:

compare a plurality of source image portions to the tile region to produce a measurement of visual similarity;

select the source image with the highest measurement of visual similarity to represent the tile region; and

position the selected source image in the mosaic image at a locus corresponding to the locus of the tile region.

16. The apparatus of claim 15 wherein the mosaic generation software is further operative to divide the tile region into distinct sub-regions, each sub-region corresponding to a specific portion of the source image, each respective sub-region being compared with each respective source image portion to produce the measurement of visual similarity.

17. The apparatus of claim 16 wherein the source image employed for comparison with the tile region has one pixel per respective sub-region.

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

18. The apparatus of claim 15 wherein the mosaic generation software is further operative to compute the average Root-Mean Square error of Red, Green and Blue channels.

19. The apparatus of claim 15 wherein the mosaic generation software is further operative to remove selected source images selected from consideration such that no one source image appears more than once in the mosaic image.

20. The apparatus of claim 15 further including video equipment selected from the group consisting of a video tape player and a videodisc player, said video equipment being operative to capture source images for storage in a database in the computer workstation.

21. The apparatus of claim 20 wherein modified source images are generated by cropping and resizing the captured source images to a consistent size.

22. The apparatus of claim 21 wherein, in the case of a captured source image in landscape format, the captured image is cropped from center.

23. The apparatus of claim 22 wherein, in the case of a captured source image in portrait format, the captured image is cropped from above center.

24. The apparatus of claim 21 wherein the captured source images are categorized within the database.

25. The apparatus of claim 21 wherein the captured source images are stored at different levels of resolution.

26. The apparatus of claim 20 further including an editing computer with software for editing the mosaic image.

27. The apparatus of claim 26 further including a printer for printing the edited mosaic image.

28. The apparatus of claim 15 wherein the source image with the highest measurement of visual similarity is deselected if it is determined that the source image has a higher measurement of visual similarity to another tile region.

29. The apparatus of claim 15 wherein at least one source image is assured inclusion in the mosaic image, the assured source image being positioned in the mosaic image at a locus corresponding to the locus of the tile region having the highest measure of visual similarity therewith.

30. The apparatus of claim 15 wherein a sub-category of source images is specified for exclusive matching with a predetermined portion of the target image.

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

ABSTRACT OF THE DISCLOSURE

A mosaic image is formed from a database of source images. More particularly, the source images are analyzed, selected and organized to produce the mosaic image. A target image is divided into tile regions, each of which is compared with individual source image portions to determine the best available matching source image by computing red, green and blue channel root-mean square error. The mosaic image is formed by positioning the respective best-matching source images at the respective tile regions.

105621

0957833 .102797

WEINGARTEN, SCHURGIN,
GAGNEBIN & HAYES LLP
TEL (617) 542-2290
FAX (617) 451-0313

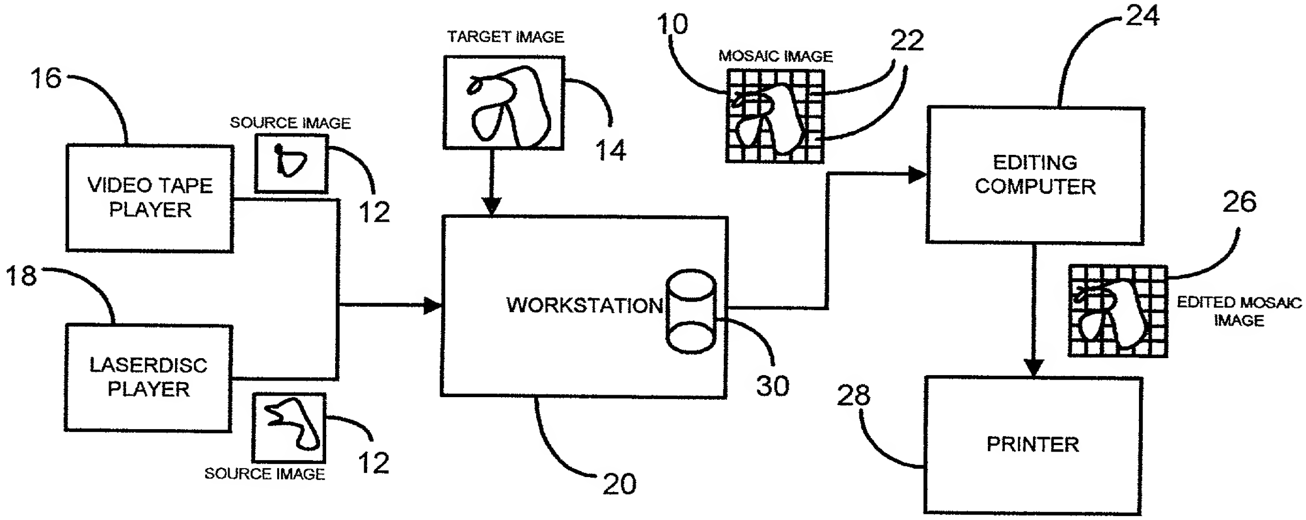


FIG. 1

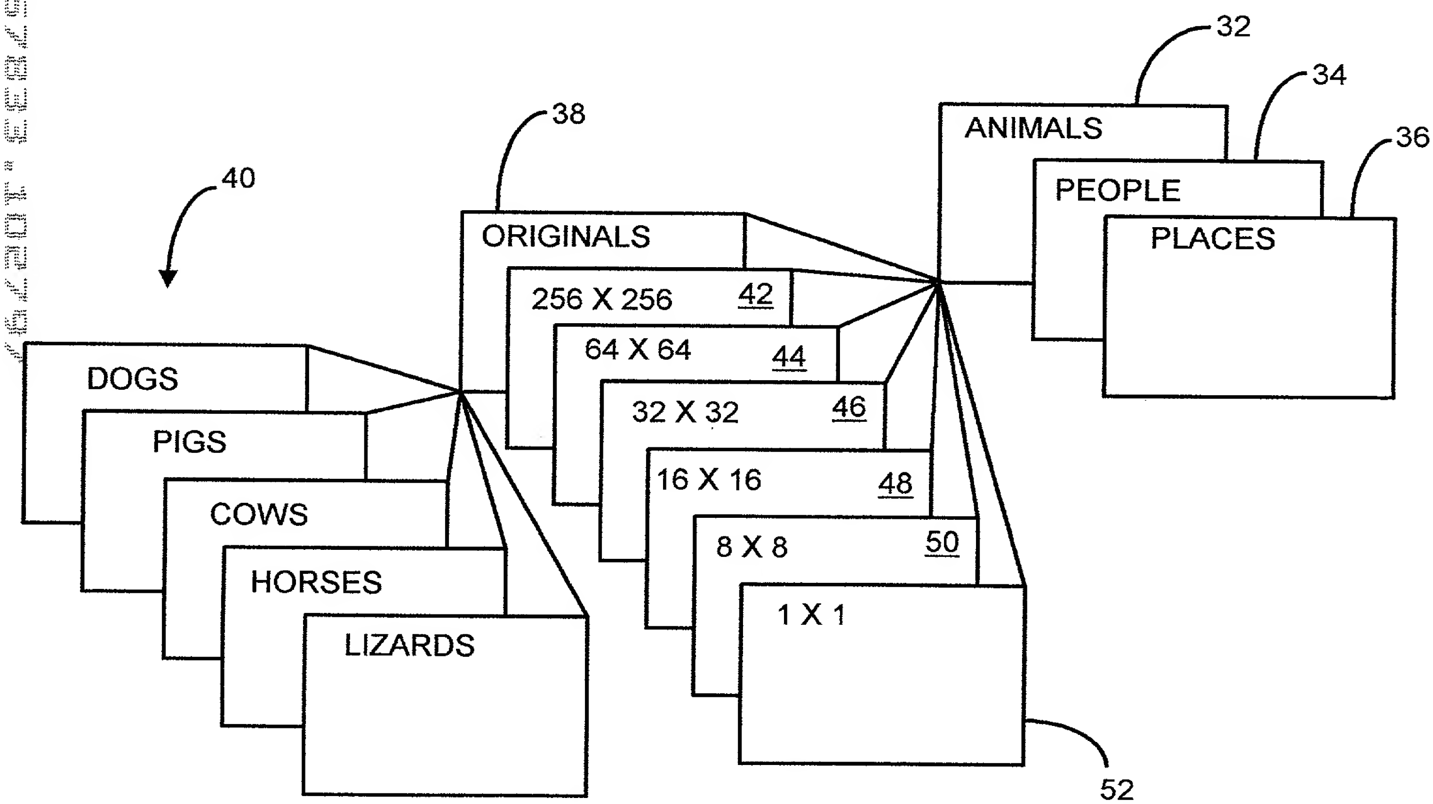
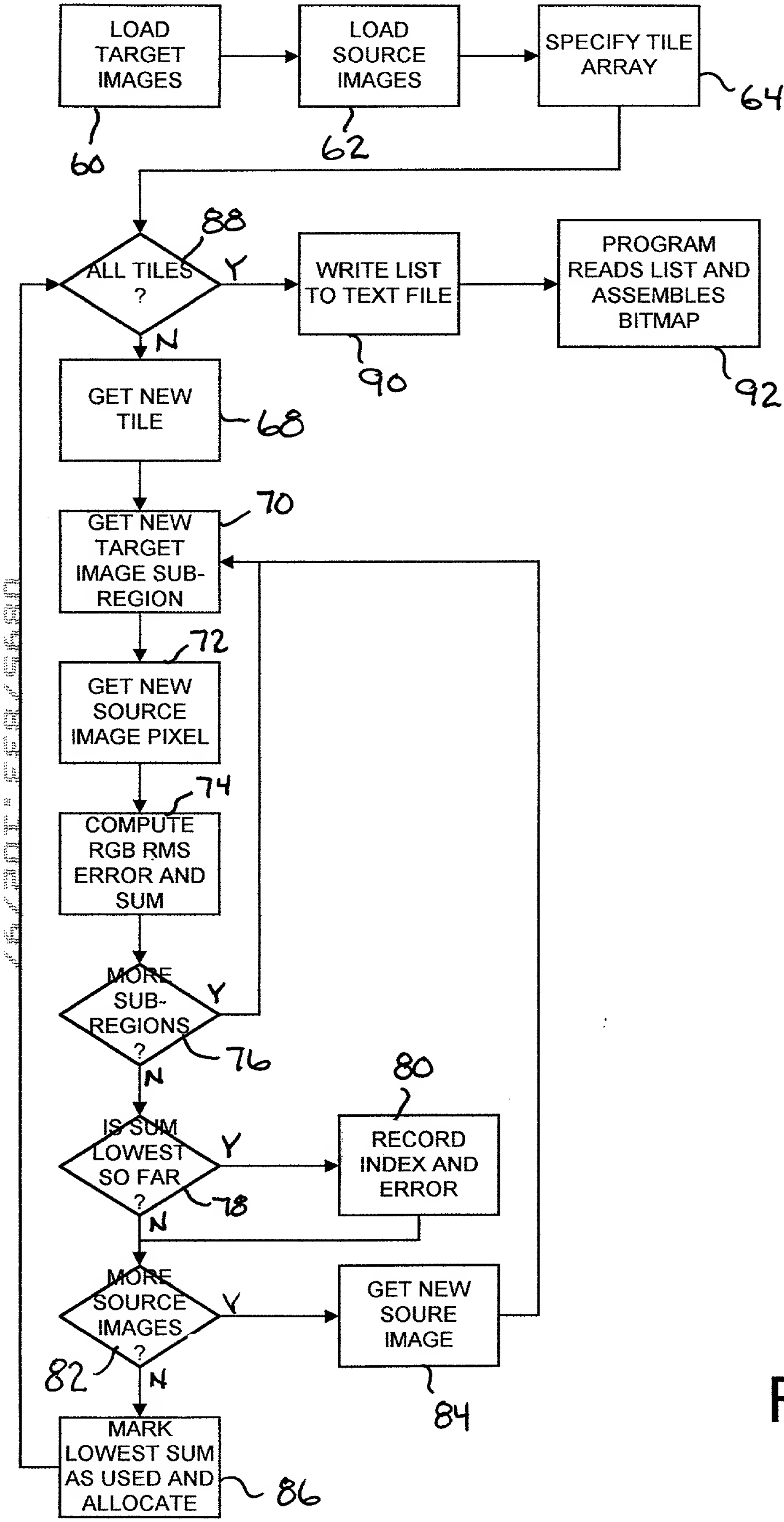


FIG. 2

Express Mail Number

EM259611263US



LOAD TARGET IMAGES
60
LOAD SOURCE IMAGES
62
SPECIFY TILE ARRAY
64
ALL TILES ?
88
Y
N
WRITE LIST TO TEXT FILE
90
PROGRAM READS LIST AND ASSEMBLES BITMAP
92
GET NEW TILE
68
GET NEW TARGET IMAGE SUB-REGION
70
GET NEW SOURCE IMAGE PIXEL
72
COMPUTE RGB RMS ERROR AND SUM
74
MORE SUB-REGIONS ?
76
IS SUM LOWEST SO FAR ?
78
RECORD INDEX AND ERROR
80
MORE SOURCE IMAGES ?
82
GET NEW SOURE IMAGE
84
MARK LOWEST SUM AS USED AND ALLOCATE
86

FIG. 3

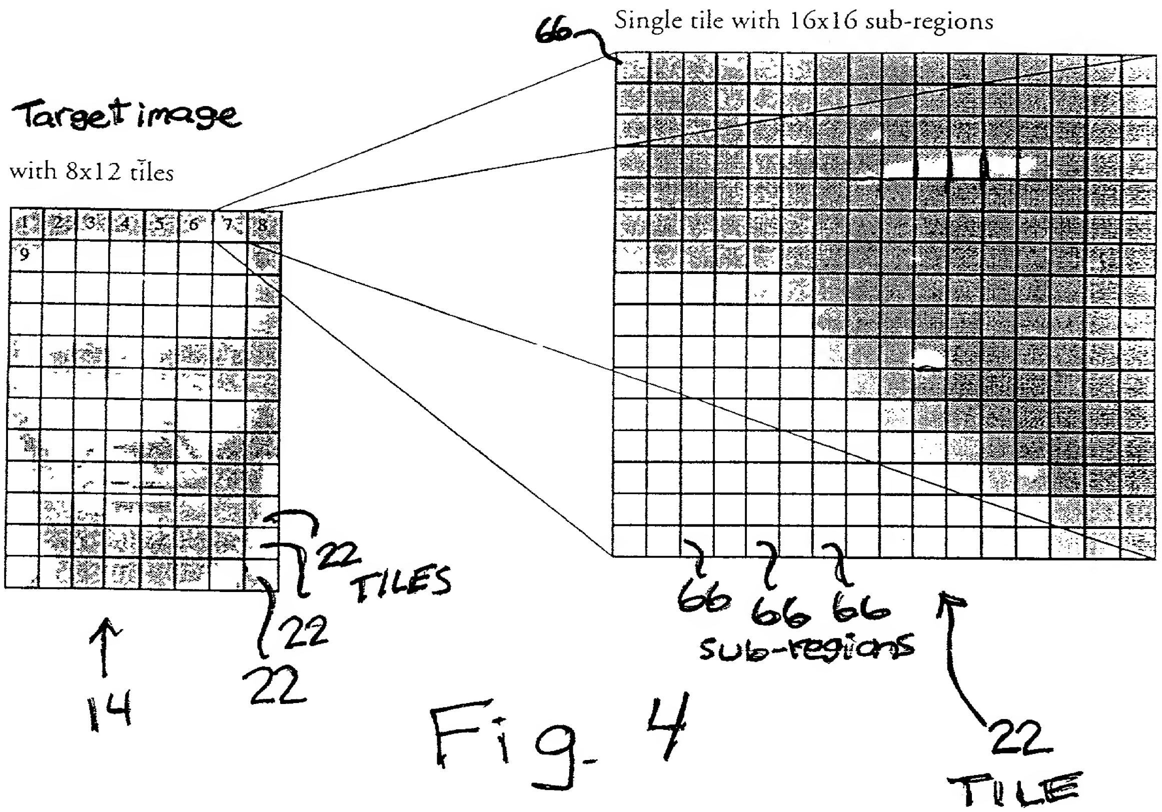

Target image
with 8x12 tiles
1
2
3
4
5
6
7
8
9
Single tile with 16x16 sub-regions
66
22
TILES
22
22
14
66
66
66
sub-regions
22
TILE

Fig. 4

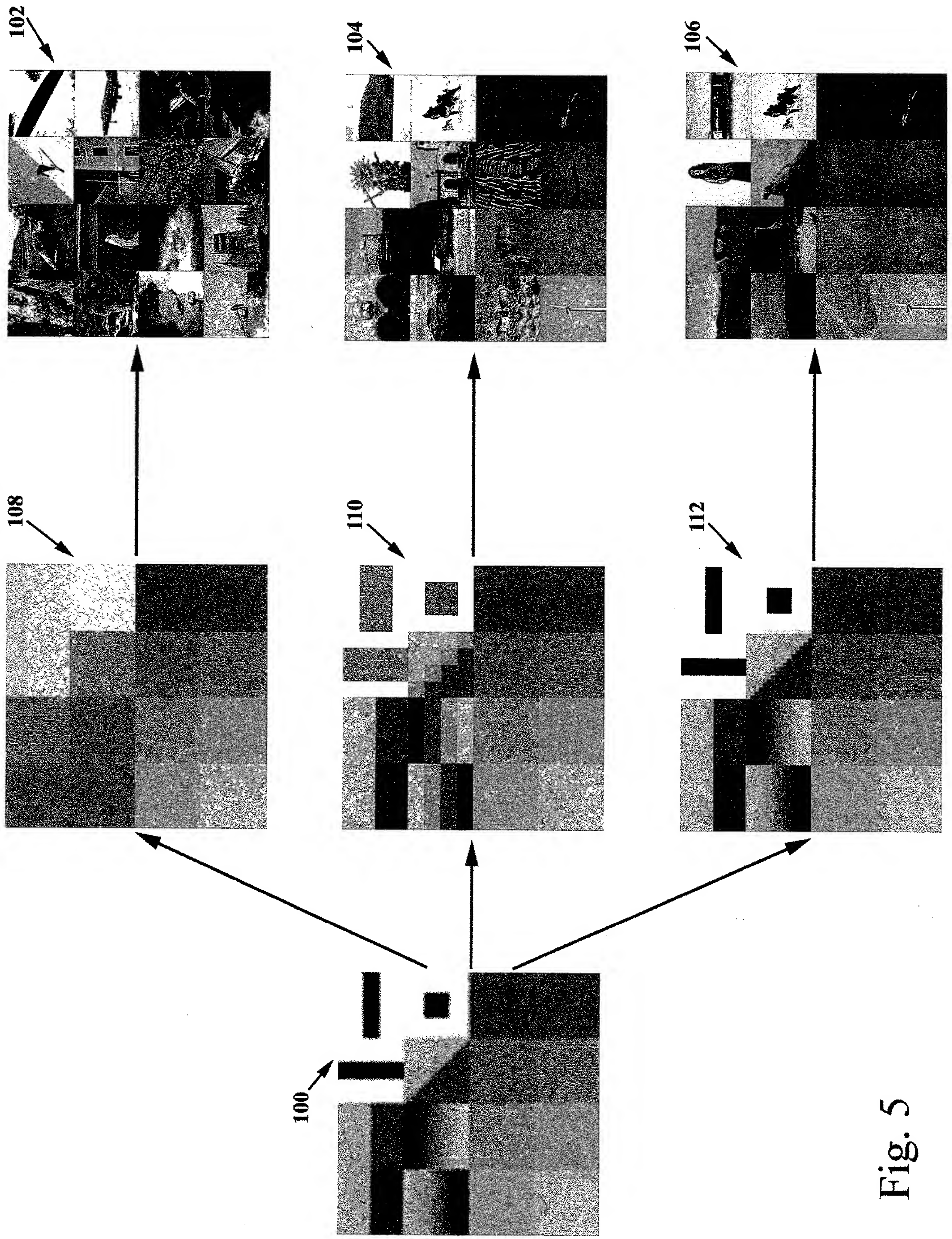


Fig. 5

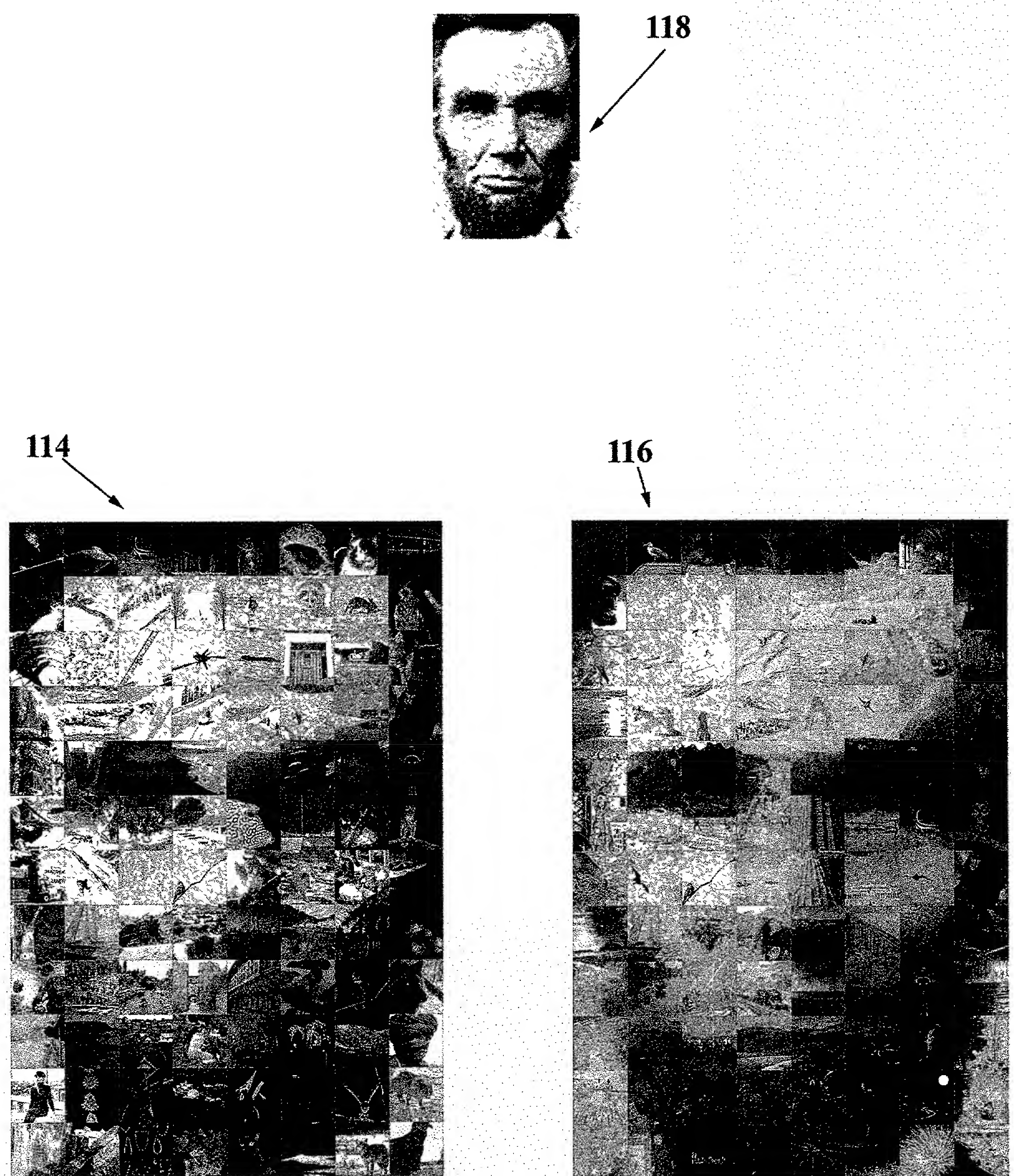


Fig. 6

Attorney
Docket No.: RTI-001XX

DECLARATION AND POWER OF ATTORNEY

As a below-named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled:

DIGITAL COMPOSITION OF A MOSAIC IMAGE

the specification of which (check one):

[X] **is attached hereto.** [ ] **was filed** ______________ **as Application No.** ____________**;**
amended on __________________________ **(if applicable).**

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations §1.56(a).

I hereby claim foreign priority benefits under Title 35, USC §119(a)-(d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)		Date Filed	Priority Claimed	
(Number)	(Country)	(Day/Month/Year)	[ ] Yes	[ ] No
(Number)	(Country)	(Day/Month/Year)	[ ] Yes	[ ] No
(Number)	(Country)	(Day/Month/Year)	[ ] Yes	[ ] No

I hereby claim the benefit under Title 35, USC §119(e) of any United States provisional application(s) listed below:

60/035,733	January 2, 1997
(Application Number)	(Filing Date)
(Application Number)	(Filing Date)
(Application Number)	(Filing Date)

Express Mail Number

EM259601126305

Attorney
Docket No.: RTI-001XX

I hereby claim the benefit under Title 35 USC §120 of any United States application(s) listed below and insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35 USC §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application No.)	(Filing Date)	(Patented/pending/abandoned)
(Application No.)	(Filing Date)	(Patented/pending/abandoned)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) to prosecute this application and transact all business connected therewith in the Patent and Trademark Office, and to file with the USRO any International Application based thereon.

Stanley M. Schurgin, Reg. No. 20,979
Charles L. Gagnebin III, Reg. No. 25,467
Paul J. Hayes, Reg. No. 28,307
Victor B. Lebovici, Reg. No. 30,864
Eugene A. Feher, Reg. No. 33,171
Beverly E. Hjorth, Reg. No. 32,033
Holliday C. Heine, Reg. No. 34,346
Gordon R. Moriarty, Reg. No. 38,973

Address all correspondence to:

WEINGARTEN, SCHURGIN, GAGNEBIN & HAYES LLP
Ten Post Office Square
Boston, Massachusetts 02109
Telephone: (617) 542-2290
Telecopier: (617) 451-0313

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full Name of Sole Inventor: Robert S. Silvers		
City of Residence Cambridge	State **or** Country Massachusetts	Country of Citizenship United States
Post Office Address 129 Franklin Street, #105	City Cambridge	State **or** Country Zip Code Massachusetts 02139
Signature: (Please sign and date in permanent ink.) **X** Robert S. Silvers		**Date signed:** **X** 10-22-97

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICANT: Robert S. Silvers

ATTORNEY DOCKET NO.: RTI-001XX

APPLICATION NO.:

EXAMINER:

FILED:

GROUP NO.:

PATENT NO.:

ISSUED:

ENTITLED: DIGITAL COMPOSITION OF A MOSAIC IMAGE

VERIFIED STATEMENT AS SMALL ENTITY

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

THE UNDERSIGNED DECLARE(S):

Exclusive rights in the above-identified invention reside in the "small entity(ies)" defined and named below, and "small entity" fees are appropriate. Qualification as a small entity is based upon the appropriately checked statements below:

[ ] INDEPENDENT INVENTOR

The below-signing independent inventor(s) has (have) not assigned, granted, conveyed or licensed, and is (are) under no obligation under contract or law to assign, grant, convey or license any rights in the invention to any person who could not likewise be classified as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

[X] SMALL BUSINESS CONCERN

The below-identified small business concern qualifies as a small business as defined in 13 CFR 121.1301 through 121.1305, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under Section 41(a) and (b) of Title 35, in that the number of employees, including those of its affiliates, which does not exceed 500 persons, and it has not assigned, granted, conveyed or licensed, and is under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who could not be classified as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Concerns are affiliates of each other when, either directly or indirectly, one concern controls or has the power to control the other, or a third party controls or has the power to control both. The number of employees of the business concern is the average over the fiscal year of the persons employed during each of the pay periods of the fiscal year. Employees are those persons employed on a full-time, part-time or temporary basis during the previous fiscal year of the concern.

Express Mail Number

EM259611263US

Attorney
Docket No.: RTI-001XX

[ ] NONPROFIT ORGANIZATION (Check additional applicable box.)

The below-identified nonprofit organization qualifies as a small entity under 37 CFR 1.9(e) in that it constitutes:

1. [ ] a university or other institution of higher education located in any country; or

2. [ ] an organization of the type described in Section 501(c)(3) of the Internal Revenue Code of 1954 (26 USC 501(c)(3)) and exempt from taxation under Section 501(a) of the Internal Revenue Code (26 USC 501(a)); or

3. [ ] any nonprofit scientific or educational organization qualified under a nonprofit organization statute of a state of the United States (35 USC 201(i)); or

4. [ ] any nonprofit organization located in a foreign country which would qualify as a nonprofit organization under paragraphs (e)(2) or (3) of Rule 1.9 if it were located in the United States.

The undersigned acknowledge(s) the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate (37 CFR 1.28(b)).

The below-signing individual(s) hereby declare(s) that (he, she, they) are authorized to execute this statement on behalf of the small entity; that all statements made herein of (his, her, their) own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Name of Small Entity: (Independent Inventor/Small Business/Nonprofit) Runaway Technology, Inc.	
Address of Small Entity: (Street, City, State **or** Country, Zip Code) 875 Main Street, 4th Floor, Cambridge, Massachusetts 02139	
Name of Person Signing: (Small Business/Nonprofit) Robert S. Silvers	
Title of Person Signing: (Small Business/Nonprofit) President and CEO	
Signature: (Please sign and date in permanent ink.) **X** Robert S. Silvers	**Date signed:** **X** 10-22-97

EAF/rec

109930

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application	:	Robert S. Silvers
Filed	:	Herewith
For	:	DIGITAL COMPOSITION OF A MOSAIC IMAGE
Attorney's Docket	:	RTI-001XX

* *

Express Mail Mailing Number EM259611263US
Date of Deposit - October 27, 1997

I hereby certify that the following items are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and as addressed to BOX PATENT APPLICATION, Assistant Commissioner for Patents, Washington, D.C. 20231:

U.S. Patent application of Robert S. Silvers, entitled DIGITAL COMPOSITION OF A MOSAIC IMAGE, consisting of

<u>Specification includes:</u>

PP 1 through 14 of Specification; PP 15 through 20 of 30 claims and Abstract; Informal drawings consisting of First sheet of Figs. 1-2; Second sheet of Fig. 3; Third sheet of Fig. 4; Fourth sheet of Fig. 5; and Fifth sheet of Fig. 6, and including Declaration and Power of Attorney original signature; Verified Statement of Small Entity; and Information Disclosure Statement (2) References, together with a check in the amount of $505.00 to cover the filing fee thereof and a cover letter in triplicate;

An Assignment of the invention and application for recording Robert S. Silvers to RUNAWAY TECHNOLOGY, INC. comprising 3/pages including Recordation Form Cover Sheet signed by Eugene A. Feher; and a check in the amount of $40.00 to cover the Assignment recording fee.

The above items are deposited with signatures and dated by the filing attorney as appropriate.

Stephen Arnold

EAF/rec
rev. 3/97

* *

(Express Mail Transmittal Letter Continued Next Page)
110465

Express Mail Transmittal Letter
Page -2-

Express Mail Label Number: EM259611263US
Attorney's Docket: RTI-001XX

PLACE OF DEPOSIT ______________________________

TIME OF LAST SCHEDULED PICK-UP
FOR THAT PLACE AND DATE OF DEPOSIT ____________

DATE OF DEPOSIT ______________________________

TIME OF DEPOSIT ______________________________

DATE OF ENTRY ______________________________

TIME OF ENTRY ______________________________

DEPOSITOR'S INITIALS __________________________

EAF/rec
110465